Model Checking for an Alarm System Earthquake Detection using UPPAL Tool

Esthephany Tanco Corrales, Student[1], Carlos Yucra Condori, Student[1] , Joao Benavente, Student[1] , Elizabeth Vidal Duarte, Mentor[1]

[1]*Universidad Nacional de San Agustín, Perú, etancoc@unsa.edu.pe, cyucrac@unsa.edu.pe, abenaventemay@unsa.edu.pe, evidald@unsa.edu.pe*

***Abstract–** Natural disasters such as earthquakes can have negative impact on society by causing structural damages, human loses, and economic losses. Arequipa is exposed to constant earthquakes which can not be prevented because there is not a system of alarms that anticipate them. This article presents the first phase of a proposal for the implementation of an Alarm System for Earthquakes detection. Since it is a critical system a formal model is needed. We use Model Checking with UPPAL tool to verify the required properties of the Model.*

***Keywords:** Instituto Nacional de Defensa CIVIL (INDECI) , Instituto Geofísico del Perú (IGP) .*

I. Introduction

Today we reliance on the functioning of software. Software is becoming more and more complex and are massively encroaching on daily life and all kinds of embedded systems, mobile phones, and high-risk software. System verification techniques are being applied to the design of critical software. System verification is used to establish that the design or product under consideration possesses certain properties. This specification prescribes what the system has to do and what not, and thus constitutes the basis for any verification activity [1].

This paper presents the initial design for an Alarm System Earthquake Detection using. Then the initial formal model will be validated with Model Checking UPPAL Tool in order to verify properties of reachability and safety. The rest of the article is organized as follows. In section 2 we present related works. Section 3 presents the main characteristics of Model Checking. In the section 4 we present our study. Finally in section 5 the conclusions are presented.

II. Related Works

There are different experiences related to anticipate earthquakes detection. Nakamaru and Saita [2,3] present UrEDAS, a earthquake warning system that can realize the real-time early earthquake detection and alarm system in the world. It comprises of a single station including three component seismometers that provides information on magnitude, location and depth of the earthquake. Also, describes the method used to determining earthquake parameters with P-wave.

Horiuchi [4] developed a Real-Time Earthquake Information System that determines earthquake parameters within a few seconds from the arrivals of the P-waves at the closest stations, and then broadcasts earthquake alarm information. He introduced a novel method of hypocenter locations by using not only the P-wave arrival times but also the fact that P waves have not yet arrived for many stations.

Ashiya [5] points out Railway Technical Research Institute (RTRI) has established a new algorithm in evaluating quickly seismic source parameters (magnitude and epicenter location) from the initial part of P-waves and developed a new earthquake quick alarm system "EQAS". Other specific works on earthquake detection and alarm system are developed in [6,7].

In this paper, our propose a model checking for an Alarm System Earthquake Detection in real-time such as [1] and [2], for this we use the tool UPPAL.

III. Model Checking

A. Definition

The models describe possible behaviors of the system in an unambiguous way arises from the problem of many ambiguities and inconsistencies of the informal specifications that are detected when modeling without the need to verify the model. Then the verification of models is a technique that, given a finite model of a system and a formal property, verifies by means of a tool [1].

A system is validated by means of model checking first, the inputs are the formal requirements and the modeling of the system having them ready, we proceed to do the verification (model checking) to determine if our proposal is correct, otherwise if a violation or examples have occurred by means of a simulation, errors must be found to correct them later. A model is built as a set of concurrent processes. Each process is graphically designed as a timed automaton. Since instantiations of the same automaton are frequently needed templates are used. A timed-automaton is represented as a graph which has locations as nodes and edges as arcs between locations (Fig. 1).

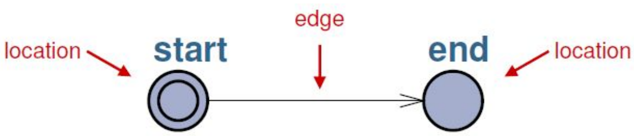

Fig. 1 State Machine

Edges are annotated with guards, updates, synchronisations and selections. A guard is an expression which uses the variables and clocks of the model in order to indicate when the transition is enabled, i.e. may be fired. (Fig. 2)

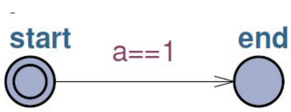

Fig 2. Using Guard

B. UPPAAL Tool

UPPAAL is an integrated tool environment for modeling, validation and verification of real-time systems modeled as networks of timed automata, extended with data types (bounded integers, arrays, etc.) . The tool was developed in collaboration between the Department of Information Technology at Uppsala University, Sweden and the Department of Computer Science at Aalborg University in Denmark. UPPAAL is free for non-commercial applications in academia only. For commercial applications a commercial license is required [8].

UPPAAL has three main parts: editor , simulator an verifier.

B.1. Editor: In Fig. 3, we show the editor. It will let us draw our Model as a State Machine diagram.

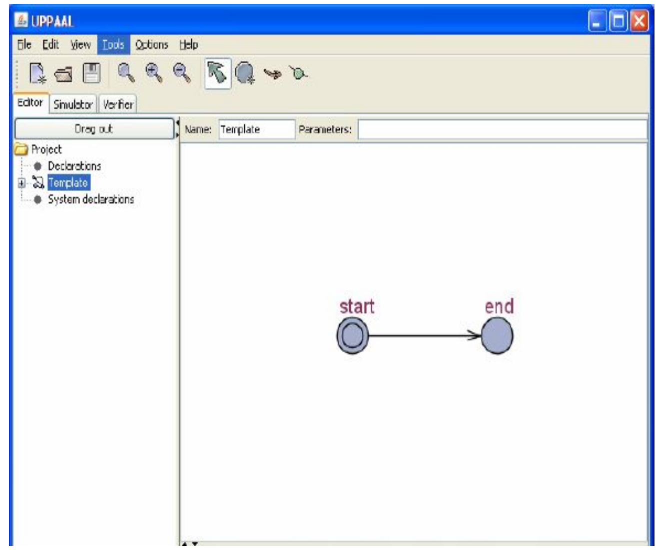

Fig. 3 Editor Uppal

B.2. Simulator: The simulator shows us the follow-up from the START with the possible ways to continue to reach our goal the FIN as seen in Fig. 4. Where we can go back to the previous step or continue, we can also go slow or fast, or repeat the follow-up again.

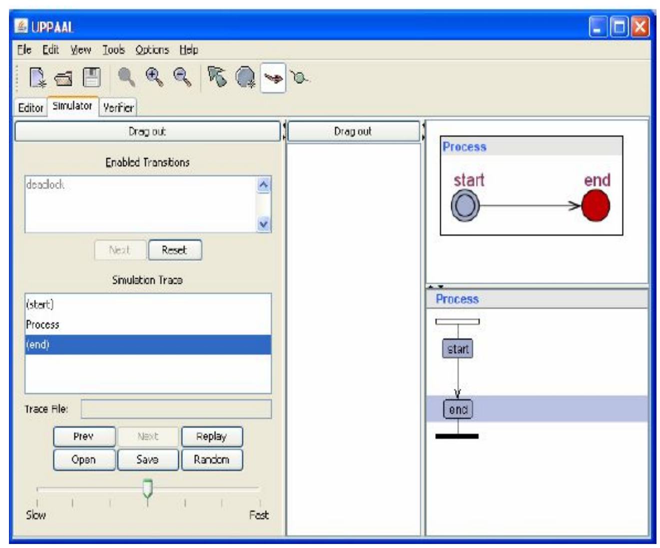

Fig.4 Simulator Uppal

B.3. Verifier

After using the simulator to ensure that the model behaves as the system we wanted to model (and sometimes also to detect some errors in the original design), the next phase is to check that the model verifies the properties. Then we need to decide what those properties are and formalize them. We need to translate those properties into the UPPAAL query language. We will work with two kind of properties

1. **Reachability properties:** A specific condition holds in some state of the model's potential behaviors. They are always expressed in the form: `E<> p` "Exists eventually p". It means there is an execution path in which p eventually (in some state of the path) holds

2. **Safety properties:** A specific condition holds in all the states of an execution path. Two possibilities:

   `E[] p` "Exists globally p". It means there is an execution path in which p holds for all the states of the path.

   A[] p "Always globally p". For each (all) execution path p holds for all the states of the path

In Fig. 5, we show the verifier.

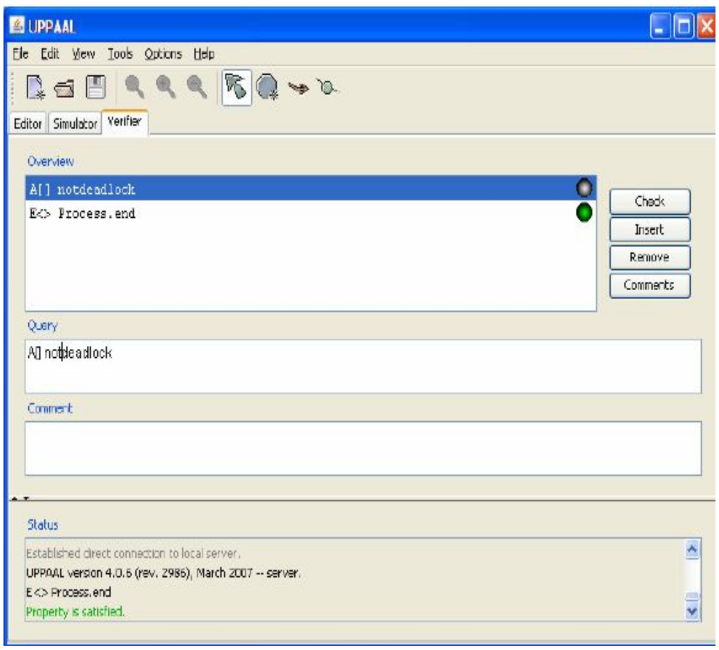

Fig.5 Verification Uppal

IV. Application Case

A. Problem Description

Perú is a country where large-scale earthquakes occur frequently, which cause disasters, deaths and economic losses. This happens because there is no warning when an earthquake is going to happen and people can take refuge in a safe place.

According to the INDECI it shows the totality of earthquakes that occurred in Peru, the place, the latitude, the magnitude and other details where it is shown that Peru is a highly seismic place [12].

In Fig. 6 shows that on June 23, 2018 in Arequipa there was an earthquake of magnitude of 8.2, which resulted in 74 deaths, 2689 injured, 217495 victims, 64 missing, 35601 homes affected and 17584 homes destroyed according to INDECI [10].

Fig.6 Earthquake in Arequipa - Perú 2001

In Fig. 7 shows that this January 14, 2018 in Arequipa in the province of Caravelí had an earthquake of magnitude of 7.1 as indicated by to IGP [11], where I leave as a consequence 01 dead person and about 60 people killed according to the INDECI [12].

Fig.7 Earthquake in Arequipa – Perú 2018

B. Proposal

It is proposed to develop an earthquake alarm system that can determine hypocentral parameters within a few seconds by using P-wave data, and then broadcast earthquake alarm information before the arrival of the larger-amplitude S waves.

We take as a basis the proposal made by a large number of researchers. That the first impulse of a P wave was sometimes a compression and sometimes a rarefaction was an observation observed at the beginning of the history of seismology. In 1909, Galitsin [9] was probably the first to establish this fact with certainty.

C. Functional Requirements

We have founded our project in the work made by [2]. Following his model we had identified the following requirements:

R1:The seismometer detects the waves P.
R2:The seismometer detects S waves.
R3:The system activates earthquake alarms.
R4:The system deactivates earthquake alarms.
R5:The system calculates the arrival time of the S waves to the different places.
R6: The system calculates the magnitude of the waves P.

D. Class Diagram

The class diagram explains the interaction of each element of the system. First we have a system that controls everything is the master, to the signals coming from the sensors where the system can give a signal of whether or not to the alarms that it controls as shown "Fig 8".

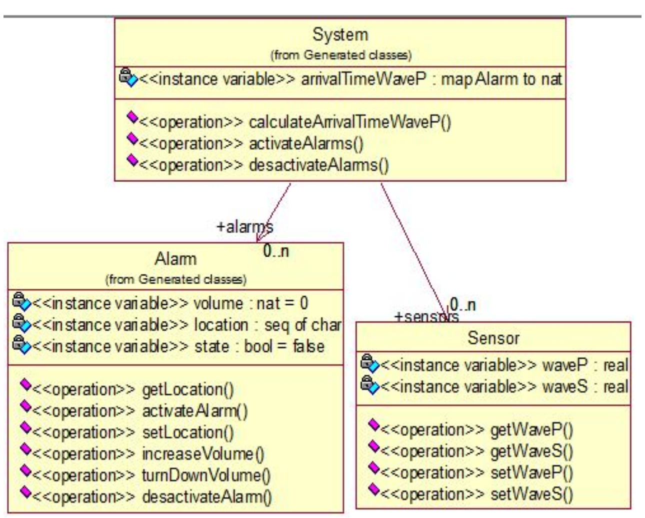

Fig. 8 Class diagram of Earthquake Detection and Alarm System

E. State Transition Diagram

Figure 9 describes the State Transition Diagram. It starts with the sensors activated at zero and the alarms on, then if the signal coming from the sensor is low or zero then it remains in the same state (off), then if a sensor comes from a Considerable signal is increased by a Sensor Activated counter, if that counter reaches 20 then the alarms are activated. After that, after 120 seconds the alarms go off and the initial state is restored as shown "Fig 9".

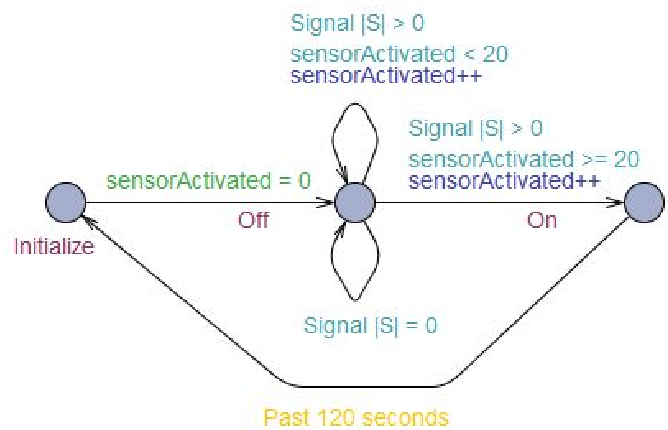

Fig. 9 State Transition Diagram of Earthquake Detection and Alarm System in UPPAAL

V. Conclusions

In this paper, we presented the design of an earthquake alarm system conform by sensors that detects the waves P, and alarms controlled for a system.

In order for our model checking to be the best, we tested it in the UPPAL tool, in which we can visualize the procedure to obtain an earthquake alarm in real time, which would help us in the future to prevent and reduce deaths and material losses. Since there is currently no model checking in Peru, being a highly seismic country like the city of Arequipa.

VI. References

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